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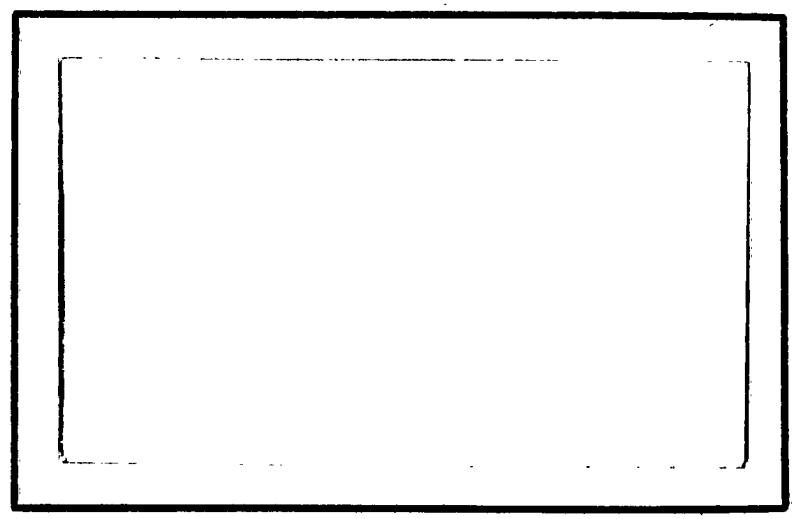

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HYDROGRAPHY OF THE WESTERN ATLANTIC; Multiple Currents in the Gulf Stream System

By

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Director

MULTIPLE CURRENTS IN THE GULF STREAM SYSTEM*

In nearly all discussions of the Gulf Stream and of the North Atlantic Current the terms countercurrent and eddy are frequently employed, (ISELIN 1936, 1940, and SVERDRUP et. al. 1942). Many temperature and salinity profiles across the currents indicate the presence of countercurrents and/or eddies and certain theoretical considerations require that they exist (ROSSBY 1936). On the other hand charts showing the average distribution of temperature and salinity (WÜST and DEFANT 1936 and FUGLISTER 1947, etc.) and charts showing the currents in the western North Atlantic do not indicate that countercurrents or eddies are permanent features of the system.

It is the purpose of this paper to suggest that, by eliminating the averaging processes, countercurrents can be introduced as, at least, semipermanent features of the circulation and a new picture of the current system will evolve. The existing current charts fall into two general classes, those that show a relatively narrow current flowing from Cape Hatteras to the Grand Banks area where the current is shown to fork or branch, and those charts that depict a current at Cape Hatteras that gradually broadens as it moves toward the mid-Atlantic. The data used for these charts interpreted in a different manner shows that,

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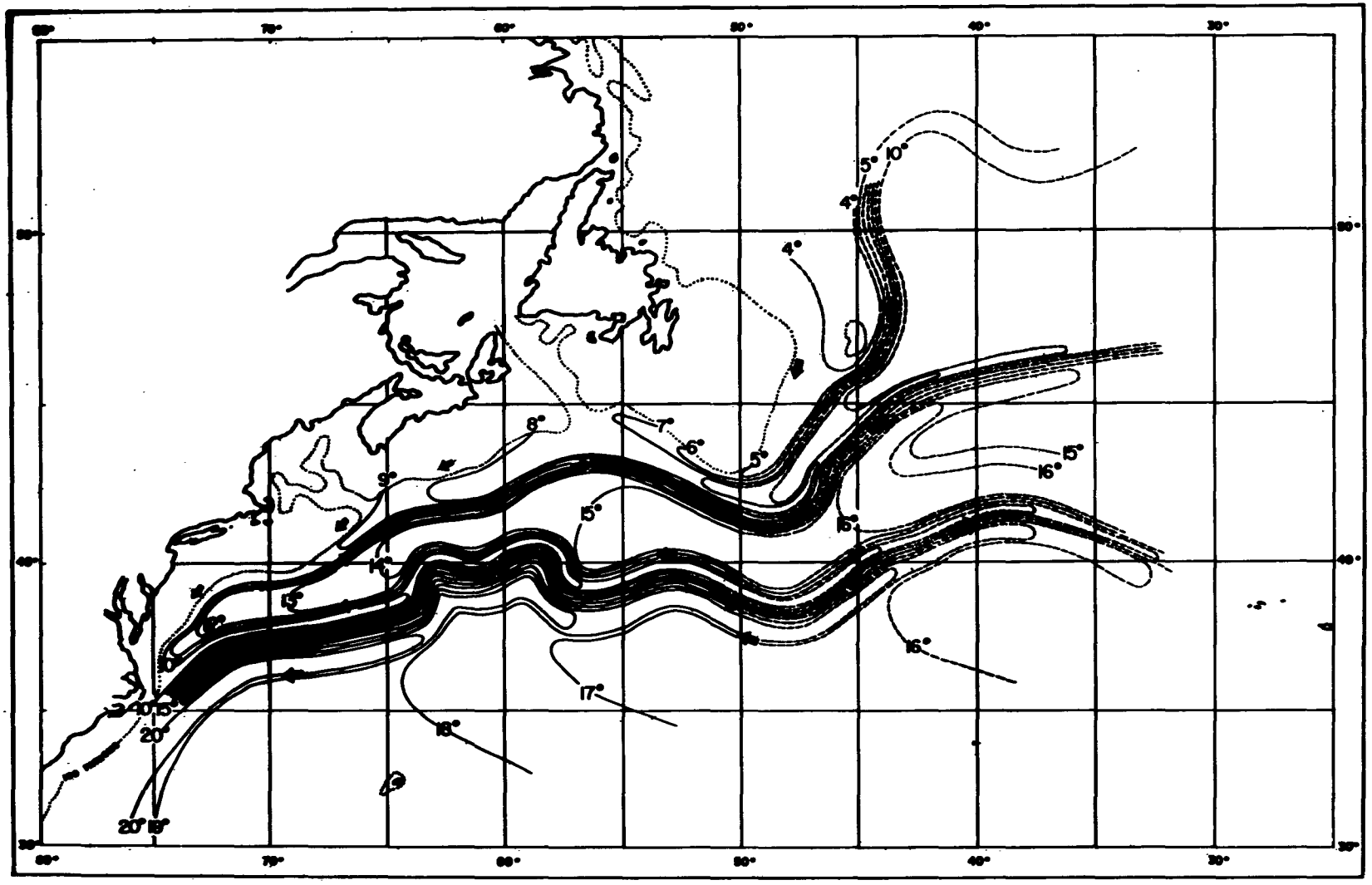
* Contribution No. 584 from the Woods Hole Oceanographic Institution.

in the Gulf Stream and North Atlantic Current Areas, there is no one continuous current but a series of overlapping easterly currents separated by countercurrents.

The averaging processes tend to obscure certain details that are known to exist. Perhaps the most important of these details, in the present connection, is the very narrow zone of minimum temperatures or low pressure generally found on the left-hand side, facing downstream, of a strong current. In an attempt to show this zone and to illustrate what seems a more logical interpretation of the accumulated sub-surface data, a schematic chart of temperatures at a depth of 200 meters in the Gulf Stream area has been drawn. The data used are from various sources but primarily from the multiple ship survey of 1950 (FUGLISTER and WORTHINGTON 1951). This chart (see Fig. 1) shows three easterly currents between Cape Hatteras and the longitude of Flemish Cap. There is a minimum temperature zone inshore of the sharp gradient off Cape Hatteras. The temperatures in this zone increase to the east. This increase in temperature is balanced by a corresponding decrease in temperature in the warm zone to the right of the gradient. If we assume for the moment that the currents flow along the isotherms, then the major current off Cape Hatteras, without becoming wider or branching, simply becomes weaker as it flows toward the east. On both sides of this current there are weak countercurrents. A second easterly current forms just off the continental



SCHEMATIC REPRESENTATION OF TEMPERATURE (°C.) AT 200 METER DEPTH.

ARROWS INDICATE PROBABLE SURFACE LAYER CURRENT DIRECTIONS AND RELATIVE VELOCITIES.
DASHED LINES SHOW REGION WITH COMPARATIVELY LITTLE DATA.

FIG. 1

shelf north of Cape Hatteras, increases in strength as it flows toward the Grand Banks area and then in its turn gradually weakens in the same manner as the first current. Finally, a third stream is depicted forming in the Grand Banks area and moving toward the northeast.

In order to check on the above interpretation of data obtained from various sources, a survey was made of part of the area by the ALBATROSS III in June 1951. The data collected on this cruise consisted of half-hourly bathythermograph observations to a depth of 250 meters and (over many sections) hourly surface current measurements with the GEK (VON ARX 1950). As was the case with the multiple ship survey of 1950 the majority of surface current vectors showed the same current directions as would be deduced from a plot of the 200-meter isotherms. A plot of these isotherms and the track of the ALBATROSS III are shown in Figure 2. The entire area of interest could not be covered in the 26 days the research vessel was at sea but the results obtained strongly support the multiple current hypothesis. In fact the data indicated the existence of four major easterly currents separated by countercurrents of varying magnitudes.

Aside from the extravagant amount of extrapolation used in both Figure 1 and Figure 2 the most serious criticism of the multiple current hypothesis as presented here may be that the temperature structure at 200 meters does not reflect the pressure field. It may be considered

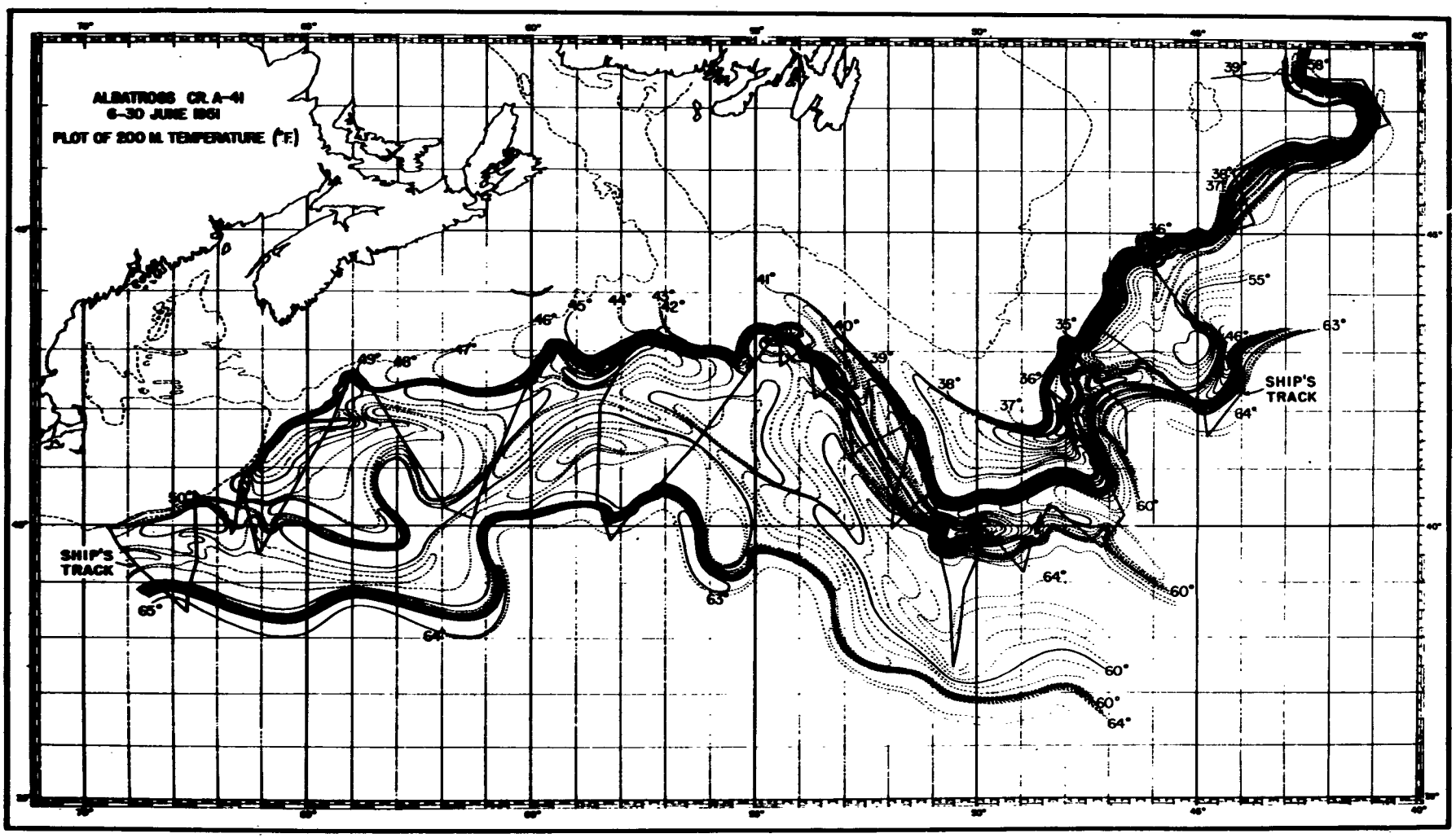

ALBATROSS CR. A-41
6-30 JUNE 1951
PLOT OF 200 M. TEMPERATURE (°F.)
SHIP'S TRACK
SHIP'S TRACK

FIG. 2

as representing only a relatively shallow surface layer. Actually a similar picture of the current regime in this area could be obtained by using surface dynamic height anomalies referred to the 2000 decibar surface. The difficulty would be that observations taken over a period of more than 10 years would have to be used and even more extrapolation would be required.

However, an examination of all the available deep temperature and salinity sections normal to the coast between Cape Hatteras and the Grand Banks gives the following interesting results. Out of fifteen sections between Montauk, Long Island, and Bermuda, variations in the depth of the sigma-t 27.2 surface show:

7 sections with a slight westerly current very close in by the continental shelf;

13 sections with a stronger easterly current just off the shelf;

13 sections with a countercurrent to the left of the Gulf Stream;

12 sections with a countercurrent to the right of the Gulf Stream.

The average depth in meters of the 27.2 sigma-t surface at each maximum and minimum point from the shelf outward is as follows:

average	255	231	336	214	949	833
difference	-24	+105	-122	+735	-116	

Of the available sections to the east of the Montauk-

Bermuda line and west of the 50th meridian only 7 reach from the continental shelf out to the Gulf Stream. These 7 all show an easterly current off the continental shelf and a countercurrent between it and the Gulf Stream. None of these sections reached far enough south to check on the existence of a countercurrent to the right of the Stream. When the data from the three most easterly sections are averaged, the depth of the sigma-t 27.2 surface at each maximum and minimum point from the shelf outward is:

average	190	132	487	383	890
difference	-58	+355	-104	+507	

Assuming that the differences in depth of the sigma-t surface between these points indicate the relative strength of the currents then it appears that the easterly current off the continental shelf increases and the Gulf Stream decreases in strength as they move toward the Grand Banks area.

If this multiple current system is accepted, then there is a problem of nomenclature. As a group the currents discussed here form a portion of the Gulf Stream System. This portion of the System fits the description of the North Atlantic Current, as given in THE OCEANS (SVERDRUP et. al. 1942), except that now the name should apply to the group of currents as far west as Cape Hatteras instead of only to those currents to the east of the Grand Banks. If the term Gulf Stream is to be retained, it should be understood that it applies only to the direct continuation

of the Florida Current and it does not include all easterly-flowing currents between Cape Hatteras and the Grand Banks. Whether or not any of the other currents in the group should be specifically named is a question that might wait until more is known about their permanency.

Since June of this year, the ALBATROSS III has been engaged in surveying the area to the east of Flemish Cap. Aboard ship the various currents are referred to as No. 1 (for the Gulf Stream), No. 2, No. 3, etc., for each successive current encountered. No. 4, the current off Flemish Cap, has been followed as far east as the 23rd meridian and the possible existence of a No. 5 has been indicated.

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